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Atlantic Salmon Habitat Survey: Enhancement Opportunities and Problems in the Dunbar Stream, Nashwaak River, New Brunswick

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**ATLANTIC SALMON HABITAT SURVEY:
ENHANCEMENT OPPORTUNITIES AND PROBLEMS IN THE
DUNBAR STREAM, NASHWAAK RIVER, NEW BRUNSWICK**

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ABSTRACT

Semple, J.R. 1991. Atlantic salmon habitat survey: enhancement opportunities and problems in the Dunbar Stream, Nashwaak River, New Brunswick. Can. MS Rep. Fish. Aquat. Sci. 2076:35p.

A total of 15.2 kilometres of the Dunbar Stream and its tributaries was surveyed to estimate its area and quality of salmon habitat. Water quality suitable for salmon production and juvenile growth below Dunbar Falls was found superior to that in other parts of the Nashwaak River system. However, low summer flows would likely prevent development of an early-run strain in the Dunbar tributary.

Based on the surveyed habitat area (106,395 m²) and various stated assumptions, it was estimated that full production of a given brood year would minimally contribute about 560 adult salmon to all fisheries and to spawning escapement, an additional 874 rod-days of recreational salmon fishing, and an economic benefit of \$9,600.

The main obstacle to natural utilization by Atlantic salmon is Dunbar Falls, located about 0.8 km upstream from the river mouth. Unless some means of passing salmon beyond the falls is provided and limited hatchery stocking implemented, or an annual stocking program is expedited, the salmon potential of this stream will go untapped.

RÉSUMÉ

Semple, J.R. 1991. Atlantic salmon habitat survey: enhancement opportunities and problems in the Dunbar Stream, Nashwaak River, New Brunswick. Can. MS Rep. Fish. Aquat. Sci. 2076:35p.

On a examiné une tranche de 15,2 kilomètres du ruisseau Dunbar et de ses tributaires dans le but d'y estimer la superficie et la qualité de l'habitat du saumon. Cette étude a permis de déterminer que la qualité de l'eau est plus propice à la production de saumon et à la croissance des juvéniles en aval des chutes Dunbar que dans le reste du réseau hydrographique de la rivière Nashwaak. Toutefois, en raison de son faible débit estival, il est peu vraisemblable que le ruisseau Dunbar soit le siège de montaisons hâtives.

En se fondant sur la superficie de l'habitat examiné (106 395 m²) et sur les diverses hypothèses formulées ici, on estime que l'aport de la production totale d'une année de génération donnée s'établirait à tout le moins comme suit : environ 560 saumons adultes pour toutes les pêches et les échappées de reproducteurs, quelque 874 journées de pêche sportive du saumon et des retonnées économiques de 9 600 \$.

Le principal obstacle à l'utilisation naturelle de cet habitat par le saumon de l'Atlantique est la présence des chutes Dunbar, situées à environ 0,8 km en amont de l'embouchure de la rivière. A moins d'aménagements quelconques permettant de faire passer le saumon au-delà des chutes, associés à une implantation minimale de saumons d'écloserie, ou d'un programme annuel d'empoissonnement, le potentiel de production de saumon du ruisseau restera inexploité.

INTRODUCTION

Dunbar Stream flows into the Nashwaak River about 1.8 km above Durham Bridge and about 30 km above the Town of Marysville (Fig. 1). The Nashwaak River in turn, flows into the Saint John River at Fredericton (at Barker's Point). The stream passes through an area of sedimentary rock which imparts a low to moderate biological productivity to the surface water (Smith 1963). Forest harvesting is the main economic activity in the watershed. The drainage area of approximately 111 km² has been heavily logged, particularly along the north shore of the main stem, in the interval between the north and south branches, and along the mid-reaches of the south branch (Fig. 1). A few farming plots are located in the headwaters of the stream along Woodland Road. It is acknowledged as a good brook trout (Salvelinus fontinalis) stream by local anglers.

The Nashwaak River has two main branches called the north and south branches Dunbar Stream and few lakes. North Branch Dunbar Stream divides into Tinkettle and Seymour brooks about 3.4 km upstream from its mouth. Vehicle access to the stream is poor. Most of the large network of logging roads and cart tracks are difficult to travel on and parallel the stream some distance from it. From its headwaters in the south branch, Dunbar Stream drops about 270 m to its convergence with Nashwaak River.

A waterfall 0.8 km from the mouth of the Dunbar Stream forms an impassible obstruction to Atlantic salmon (Salmo salar), preventing them from colonizing the habitat above. Because of the strategic location of Dunbar Stream in relation to major population centres - Marysville, Nashwaaksis, and Fredericton - and because of the high salmon angling demand on the Nashwaak River, it was decided to conduct a fish habitat survey of the stream to judge its suitability for Atlantic salmon production.

In 1968, salmon angling effort on the Nashwaak River was 66.8 percent of the total salmon angling effort in the entire Saint John River system (Smith 1981), the largest river in New Brunswick (Appendix A). This proportion averaged 48.5% in 1970-74, 21.1% in 1975-79, and 15.3% in 1980-82, while angling effort in the Nashwaak River rose from an annual average of 3,209 rod-days during 1975-79 to 4,485 rod-days during 1980-82.

The increasing demand for salmon angling and the need for sufficient spawning escapement in Nashwaak River are nearing the point where demand is outstripping supply. This situation underlines the importance of considering the enhancement of Dunbar Stream for Atlantic salmon production.

METHODS AND MATERIALS

The habitat survey for Atlantic salmon was conducted over the period August 9-25, 1983, by walking the stream. The stream was subdivided into 100 m long sections and data obtained for water temperature, degree of shading, bottom composition, stream width and depth, and the extent of riffles, runs, flats, stills, and pools. Water temperatures (by pocket thermometer) and times were recorded at each subsection. A Ryan recording thermometer was installed at the mouth of Dunbar Stream on July 6 but malfunctioned after two days. Stream widths were measured at 50 m intervals. Length measurements were made by pacing and then

conversion to metres. The average number of paces per 100 m was established for each member of the survey crew before the survey began. Water depths were taken with a metrestick at 25%, 50%, and 75% of the stream width at each location where a width measurement was made. The degree of shading in a subsection was classified as open (< 25% shade), moderate (25%-75% shade), or dense (> 75% shade). Water type was classified as follows:

- Riffle - a shallow, fast-flowing section of stream, with a broken (ripples) water surface.
- Run - a shallow, rapid-flowing section of stream, usually deeper than riffles with coarser bottom material and an unbroken (smooth) water surface, except for eddies.
- Flat - a long slow-flowing section of stream (slower than riffles and runs), with an unbroken (smooth) water surface and a depth less than 45 cm.
- Still - same as "Flat" except depth is greater than 45 cm.
- Pool - a portion of stream where the water flows more slowly and is deeper than surrounding areas (a pocket or depression in the streambed). The water surface is usually smooth and unbroken.

Pool measurements (length, width, and depth) were guesstimated. The area of each water type was calculated by computing the area of the subsection, subtracting the pool area and then applying the estimated percent of the remaining total area comprised of riffle, run, flat, and still.

Materials on the stream bottom were classified as follows:

- Silt - < 0.1 cm (< 1/16") diameter (fine particles of earth and sand)
- Sand - 0.1-0.6 cm (1/16"-1/4") diameter
- Gravel - 0.6-6.4 cm (1/4"-2 1/2") diameter
- Cobble - 6.4-25.0 cm (2 1/2"-10") diameter
- Boulder - > 25.0 cm (> 10") diameter
- Bedrock - ledge or sheets of rock

The percent of the bottom area composed of each substrate type was recorded for each subsection.

Records were kept of the numbers and kinds of potential predators of brook trout and juvenile Atlantic salmon and of complete and partial obstructions to migrating salmon.

No attempt was made to survey the entire meander length of Dunbar Stream and its tributaries. The salmon spawning and rearing estimates given in the text are for the actual stream length surveyed. Hence, the values presented are minimum estimates of salmon rearing and spawning area. Only the more accessible portions of the main stem and its major tributaries were surveyed as these were thought to be best suited to salmon production.

A quality classification for salmon parr nursery habitat was devised based on the reviews and research of Elson (1975), Symons and Heland (1978), Knight and Greenwood (1981) and Egglshaw and Shackley (1982). Flats, stills, and pools were classed as marginal nursery habitat. Riffle/run type habitat was classed as good,

fair, or marginal, based on bottom composition and average stream depth as follows:

Good	> 50% combined cobble and boulder (at least 20% cobble)	> 18 cm deep
Fair	10-49% combined cobble and boulder, gravel up to 50%	< 18 cm deep
Marginal	< 10% combined cobble and boulder	< 18 cm deep

In the case of riffle/run type parr habitat, if the two factors determining nursery quality disagreed by one factor for a given quality designation, the higher quality rating was selected, but if both determining factors disagreed, the lowest quality designation was chosen.

Spawning areas for Atlantic salmon were classified as good or marginal, based on the substrate composition of the stream bottom where the water was accelerating and stream depth was less than 1 m, as follows:

Good	40%-80% gravel 10%-40% cobble < 20% boulder < 20% combined silt and sand
Marginal	< 40% gravel 50%-90% combined cobble and boulder < 20% combined silt and sand

The quality rating for salmon areas is based on the reviews and research of White (1942), Peterson (1978), and Knight and Greenwood (1981).

Conductivity measurements were made with a Metrohm Herisau, Model E 588 conductivity meter and converted to measurements of total dissolved solids (TDS) by employing the following regression (Lennon 1959):

$$X = 7.02 + 0.72 Y$$

where X = TDS in parts per million and Y = specific conductance in $\mu\text{mhos/cm}$ at 25°C. Measurements of pH were made with a Metrohm Herisau, Model E587 pH meter.

A population estimate (+95% confidence interval (CI) limits) of brook trout was made in a 0.5 km section of stream above Dunbar Falls and below the confluence of the north and south branches by the adjusted Peterson mark-recapture method (Ricker 1975, p.78). During the first sweep of the census area with electrofishing gear (Smith-Root Model 11-A, back-pack shocker), the upper lobe of the caudal fin was clipped and the fish were measured (fork length). The area was refished the following day and the numbers of marked and unmarked trout in the census area was recorded. A series of five spot-checks were made on Tinkettle Brook (2 sites), Seymour Brook (1 site), and the main stem of Dunbar Stream below Dunbar Falls (2 sites).

Flow measurements were made periodically between July and November at the mouth of Dunbar Stream by measuring water velocities at a series of depths across the stream with a Teledyne Gurley flow meter.

RESULTS AND DISCUSSION

HABITAT SURVEY

Fish Habitat Characteristics

Stream width and depth decreased in an upstream direction (Table 1 and Appendix B). Near the mouth, width and depth averaged 12.6 m and 17 cm, respectively, compared to 5.2 m width and 10-13 cm depth in Tinkettle and Seymour brooks. A moderate ($6-33 \text{ m}\cdot\text{km}^{-1}$) stream gradient prevailed throughout most of the Dunbar system (Fig. 2).

Riffle/run type habitat predominated in the main stem, the two main branches, and in both tributaries that were surveyed. Tinkettle and Seymour brooks had a greater percentage area of pools relative to other parts of the stream system, while the combined flat and stillwater habitat constituted only 6.2% of the total area surveyed. The stream bottom consisted mainly of coarse material (cobble and boulder) in all areas. The main stem and south branch had more boulder material than other parts of the system. Gravel was scarce in all areas and ranged from a low of 4.1% of the bottom in Tinkettle Brook to a high of 11.8% in Seymour Brook (Table 1 and Appendix 3). Near the stream mouth shade was scarce (open) but in the rest of the system it was usually moderate to dense owing to the narrower stream width and higher vegetation along the banks.

Nursery Habitat For Salmon Parr

Of the 15.2 km of Dunbar Stream that was surveyed, nearly 85% ($90,750 \text{ m}^2$) was classified as good parr rearing habitat; 14% was rated as marginal, and about 1% was classified as fair nursery area (Table 2 and Appendix C). Most of the good rearing habitat was located along the main Dunbar, and the main stems of the north and south branches.

Spawning Area

A total of $8,700 \text{ m}^2$ of good-to-fair salmon spawning habitat was identified (Table 3 and Appendix D). Nearly 60% of it was located along the main stem of the north branch before it divided into Tinkettle and Seymour brooks. Little spawning area exists between the mouth of the Dunbar Stream and Dunbar Falls. In general, the areas suitable for spawning were of spotty occurrence and relatively clean of silt. Consequently, the precision of the spawning area estimate should be interpreted in a more qualitative than quantitative light.

Holding and Resting Pools

This report defines a salmon holding pool as one which adult salmon can safely occupy for extended periods of time prior to spawning. Twelve pools were judged capable of providing safe refuge for Atlantic salmon. They were characterized as areas with water depths equal to or greater than 1.8 m at minimum

flow, slow water velocity, with or without surface turbulence and having various amounts of instream cover. The definition and characteristics of a salmon holding pool used in this report are basically those of Frenette et al. (1972).

The first holding pool is located at the foot of Dunbar Falls (Table 4). There were four deep pools on the south branch, the first of which was located about 3.7 km from the mouth. The north branch (main stem) contained five holding pools. In addition, there were numerous (64) shallower pools which could provide resting areas for salmon but, because of their depth (< 1.8 m), were considered unsafe for holding salmon for extended time periods (Table 4 and Appendix E).

Water Quality and Flow

Specific conductance and pH were measured during mid-August at 11 sites throughout Dunbar Stream (Fig. 1). Specific conductance averaged $56 \mu\text{mhos/cm}$ for all sites and 54, 49, and $68 \mu\text{mhos/cm}$ for the main stem, south branch, and north branch, respectively. Total dissolved solids (TDS) for the eleven sites averaged 48 ppm. The main stem, south branch and north branch averaged 45, 52, and 56 ppm.

Total dissolved solids, of which specific conductance is usually a good measure, are correlated with fish yield to anglers in Canadian Lakes (Ryder et al. 1974). TDS and hence nutrients are presumed correlated with trout (O'Connor and Power 1976) and juvenile Atlantic salmon production. Both salmon and brook trout occur in streams with a wide range of alkalinity and specific conductance, although high levels increase production of brook trout (Cooper and Scherer 1967) and of salmon. New Brunswick streams with a conductivity less than $40 \mu\text{mhos/cm}$ had low trout populations (Welch et al. 1977). Moreover, the small size of brook trout in headwater areas has been linked with low alkalinity (100 ppm or less) and TDS of less than 20 ppm (Lennon 1967).

The overall average pH was 6.93, with the main-stem water averaging 7.31 and the north and south branches averaging 6.54 and 7.21, respectively (Table 5). The pH levels are well within the tolerance limits (Anon 1968) of Atlantic salmon and brook trout. The relatively high pH levels were likely attributable to the buffering action of leachates from the calcareous matrix which binds the sedimentary rock deposits of the area and from calcareous and argillaceous sedimentary rock in the interval between Seymour and Tinkettle brooks.

Water temperatures during early July and August were probably approaching their seasonal highs. Temperatures during the two days of continuous recordings for July 6 and 7 ranged from 13.3°C – 19.0°C and suggest that even though temperature warm-up may be rapid, the water cools considerably overnight. The highest water temperature, 23°C , was registered on August 16 in late afternoon at the stream mouth. Morning water temperatures from 0945 until 1200 hours ranged from 13.3°C to 17.5°C , while afternoon highs ranged from 14.0°C to 23.0°C (Table 6).

The temperature regime of Dunbar Stream appears to be well suited to both trout and salmon production. Brook trout usually do poorly in waters that exceed 20°C for extended periods of time (McAfee 1966). Mullen (1958) gave the optimum temperature range for activity and feeding of brook trout as between 13° and 19°C while Raleigh (1982) considered a water temperature range of 0° – 24°C as optimal for growth and survival. Optimum temperatures for normal growth of juvenile

Atlantic salmon lie in the range of 15°-19°C (DeCola 1970); temperatures above 20°C severely restrict fishing success for adult salmon and reduce the activity of migrating salmon.

The stream-flow gauging station operated by the Inland Waters Directorate at Durham Bridge on the main stem of the Nashwaak River, is likely a good indicator of the relative monthly variation in the flow of Dunbar Stream (Fig. 3). Mean monthly flows (mean of daily flows for each respective month) at Durham Bridge (1962-79) usually peak during May, with lowest mean monthly flows occurring in August. Flows measured on Dunbar Stream during the habitat survey in August were low (0.1-0.7 m³·s⁻¹ Table 7). Based on the Durham Bridge flows and those in Dunbar Stream, it is not expected that adult salmon would enter the stream until sometime in October and November or just prior to spawning. Upstream passage may be possible in June but the scarcity of suitable salmon holding pools above Dunbar Falls would likely prohibit the development of an early-run salmon strain.

Fish Sampling and Relative Abundance

No brook trout were captured below Dunbar Falls at Sites 1 and 2 (Fig. 1, Table 8). This is not surprising because the section between the falls and the stream mouth is heavily fished by trout anglers and is probably overexploited. No juvenile Atlantic salmon were found above Dunbar Falls, except for one large salmon parr at Site 3. This lone salmon parr may have been airlifted by fish-eating birds such as kingfishers and accidentally dropped into the stream, or stocked there by an overzealous sport fisherman. The lack of salmon above the falls suggests that it forms a complete barrier to spawning adults, since juveniles were relatively numerous below the falls.

The presence of slimy sculpins (Cottus cognatus) (4 sites) and burbot (Lota lota) (1 site) at five of the six sites sampled (Table 8 and Fig. 1) suggest the relatively cool nature of this spring-fed stream, as these two species, like brook trout, are found in such locations (Scott and Crossman 1973). Slimy sculpins were abundant above Dunbar Falls, but none were sampled below it. Brook trout and slimy sculpins but no American eels, Anguilla rostrata, or cyprinids were found in Tinkettle or Seymour brooks. Cyprinids (unclassified as to species) were captured in the three main-stem sampling sites (Table 8). Eels were common at Site 3 above Dunbar Falls and were present at Sites 1 and 2 near the mouth of the stream.

In the half-kilometre section of Dunbar Stream extending downstream from the confluence of the north and south branches, there were an estimated 915 (490-1,871; 95% CI) brook trout, which equates to trout densities of 17.0 (range 9.1-34.7) ·100 m⁻² of stream area, 1,697 (range 909-3,469) ·hectare, and 182 (range 97-371) ·100 m of stream length. Welch et al. (1977) found an average of 143 trout per 100 m of stream in small clear-cut watersheds in the upper Saint John River basin of New Brunswick. The numbers of trout ·100 m of Dunbar Stream (Site 3, Fig. 1) were about 6 % higher than the average numbers (172) of brook trout ·100 m in ten small, undisturbed (control) watersheds in the upper Saint John River (Welch et al. 1977). Although a large portion of the Dunbar Stream drainage has been clear-cut, the existing riverine conditions are still capable of supporting relatively high numbers of brook trout per unit of area or length. In comparison, the highest brook trout density found annually

between 1968 and 1978 was $2.9 \cdot 100 \text{ m}^{-2}$ in nine streams or sampling sites in the Nashwaak River drainage (Francis 1980).

A total of 321 brook trout was sampled at the six electrofishing sites in Dunbar Stream, half of which were ≤ 9.4 cm (FL) long, while about 75% were ≤ 12.4 cm long (Table 9). The average fork length of trout sampled was 9.8 cm; the largest was 22.3 cm. The modes in the length-frequency distribution of brook trout (Fig. 4) at 6.7, 11.7, and 14.2 cm were similar at all sampling locations and likely reflect the modal lengths of three separate age groups (age 0+, 1+, and 2+ trout), although the fish were not aged. The frequency peak at < 3.5 cm fork length is due to clumping all fish < 3.5 cm into a single category. The mean fork lengths of underyearling (age 0+) brook trout during August for streams in seven different North American localities ranged from 5.6 to 7.8 cm with a range of 4.2-11.8 cm for individual fish (Carlander 1969). The observed mode of 6.7 cm (Fig. 4) in the present study is within the average length of age 0+ brook trout in other North American locales. Moreover, the modal lengths of 11.7 and 14.2 cm are reflective of the August lengths of age 1+ and 2+ brook trout elsewhere (Carlander 1969).

Most (62%) salmon parr ranged from 11.0 to 13.9 cm. Lengths of age 1+ and 2+ salmon parr overlapped little except in the 13.0-13.9 cm length group (Table 10). No age 1+ salmon parr exceeded 13.9 cm long; no age 2+ salmon parr were less than 13.0 cm long. Age 1+ and 2+ salmon parr averaged 11.6 and 14.5 cm long, respectively, and comprised 62.5% and 37.5% of the total salmon parr collected. Relative to the entire Nashwaak River, the respective percent contribution of age 1+ and 2+ salmon parr in Dunbar Stream is about 3% lower and about 4% higher than the eleven-year (1968-78) average (Francis 1980). Grand mean lengths of age 1+ and 2+ salmon parr in the Nashwaak River were 9.7 and 13.0 cm, respectively (Francis 1980), which is 20% and 12% lower than the average lengths of the respective age-classes in Dunbar Stream (Table 11). In relative terms, it seems that lower Dunbar Stream offers better growing conditions for juvenile Atlantic salmon than is generally found throughout the Nashwaak system. If salmon were introduced above Dunbar Falls, the resulting growth of juveniles is likely to be similar to or lower than in other parts of the Nashwaak system, given the relatively high density of brook trout occurrence.

Fish Predators

No mammalian predators of brook trout and juvenile Atlantic salmon were observed (Table 12). Kingfishers (*Megaceryle alcyon*) were most numerous in North Branch Dunbar Stream ($3.1 \text{ birds} \cdot \text{km}^{-1}$ or $4.4 \text{ birds} \cdot \text{ha}^{-1}$), and were less abundant in South Branch Dunbar Stream, Tinkettle Brook, and Seymour Brook. In the overall Dunbar system, they averaged $1.5 \text{ birds} \cdot \text{km}^{-1}$ or $2.2 \text{ birds} \cdot \text{ha}^{-1}$.

Kingfishers and merganser ducks (*Merganser americanus*) generally take young salmonids more readily than other abundant species (Eipper 1956; Elson 1962). Elson (1962) concluded that kingfishers were incapable of removing more than about one-third of the standing crop of salmon parr but, because the incidence of kingfishers, unlike mergansers, tended to be constant from year to year, that kingfisher control may be of minor importance relative to merganser control.

Fish Obstructions

The only complete obstruction to fish passage during the survey was the 3.35 m high Dunbar Falls (Fig. 5). Thirty-eight partial obstructions were observed - 5 and 9 on the main stems of the north and south branches, and 13 and 11, respectively, on the Tinkettle and Seymour brook tributaries of the north branch. These obstructions consisted primarily of fallen trees, branches, stumps, log jams, or small beaver dams, which under high stream flows may be passable to migratory fishes (Table 13). With the accumulation of further waterborne debris, they could become complete obstructions.

Potential Salmon Production and Utilization

Macphee et al. (1981) have developed production utilization models for Atlantic salmon for a number of Maritime rivers based on assumptions concerning tag returns, tag loss, tag non-reporting, and the assumption that survival of wild smolts to adults averages 15%. A modified version of the model was adapted for Dunbar Stream to account for the reopening of the commercial fishery on the Saint John River. Utilization percentages of the total estimated annual adult salmon production from Dunbar Stream are as follows:

Utilization	Percent
River	
- escapement	35
- sportfishing	15
- poaching	8
Commercial Fisheries	
- Maritime	22
- Newfoundland	11
- Greenland	9

The habitat survey indicates that Dunbar Stream might produce 559 maiden salmon and grilse annually to all fisheries and to spawning escapement. This estimate is based on an assumed production of 3.5 smolt·100 m⁻² of stream habitat and 15% survival to the adult stage. Hence, enhancement of Dunbar Stream might add about 84 salmon to the annual angling creel, 123 to the Maritime commercial harvest, and 196 for spawning escapement. Over the period 1978-82, an average of 10.4 rod-days has been required to catch an Atlantic salmon in Nashwaak River. Enhancement of Dunbar Stream may provide an additional 874 rod-days of salmon sportfishing.

In computing the benefits from the utilization of Atlantic salmon stocks, McPhee et al. (1981) used the following (1980) values - \$70 per angled fish, \$5.84 per kg of commercially caught salmon, and \$2.92 per kg of poached salmon. Commercially caught 1SW salmon and MSW salmon are here assumed to average 1.8 kg and 4.5 kg, respectively. Substitution of the proportion of 1SW and MSW Saint John River salmon harvested in the commercial fisheries and by poaching (McPhee et al. 1981, p. 71), in the salmon utilization model given above, provides estimated dollar benefits of about \$9,600 annually from salmon enhancement in Dunbar Stream when it reaches full production (559 salmon).

Enhancement Opportunities and Problems

The water quality of Dunbar Stream is suitable for brook trout and Atlantic salmon production, but low summer flows would likely negate the development of an early-run salmon strain. The single, most significant problem preventing enhancement for Atlantic salmon is the impassable Dunbar Falls. Of less concern are the partial obstructions throughout the system, which are likely passable under autumn flows, but could become completely impassable with further accumulation of waterborne wood debris. Unless some method of passing salmon is provided or unless an annual stocking program is implemented, production potential of this stream will go unharnessed.

There are four possible options for utilizing the natural salmon production capability of Dunbar Stream:

- (1) construct a conventional pool-type fish ladder at Dunbar Falls and seed the area above with salmon;
- (2) reshape a portion of the falls and deepen the plunge pool at its base to accommodate salmon passage and seed the area above with salmon;
- (3) forego the construction of a fish pass, seed the area above with salmon, seine the base of the fall, and lift adults over the impass;
- (4) manage the habitat above the falls exclusively for brook trout (maintain status quo) and forego any salmon development.

The provision of fish passage in the first option entails the construction of a run-around channel, cut in rock, with six concrete weirs on one side of the river at an estimated cost of \$56,000 (1981 dollars). Establishing a run of salmon above the falls could entail straying from wild Nashwaak River salmon and/or stocking with hatchery-reared juveniles. Reliance on stray salmon is chancy, hence additional seeding employing hatchery-reared juveniles - fry, fall fingerlings, parr, and smolts - would appear desirable. Fall fingerling releases are considered the best means of ensuring the development of a self-sustaining salmon run above the falls because:

- (1) the survival of naturally spawned salmon eggs to the fry stage would not likely exceed 10%, whereas a hatchery may achieve 90% survival (Taylor 1973).
- (2) vehicle access to the area above the falls is limited. High stocking densities of unfed or feeding fry would likely be less effective than fall fingerlings or age 1+ parr plantings because of the territorial nature of fry (Keenleyside 1962).
- (3) hatchery rearing of juvenile salmon to the smolt stage would cost more than for younger release stages and would not benefit from the natural productivity of the stream.
- (4) plantings of hatchery-reared fingerlings in mid-October to mid-November would likely reduce intraspecific competition because the feeding activity of juvenile salmon is depressed by lower water temperatures (Gibson 1978). This would allow further time for natural post-stocking dispersal prior to the resumption of active feeding in the spring.
- (5) as juvenile salmon increase in size, their preference for deeper and swifter water is enhanced (Elson 1975; Symons and Heland 1978; Knight and Greenwood

1981; Egglshaw and Shackley 1982), further contributing to the natural dispersal of fall fingerlings from release sites.

An annual release of about 23,000 fall fingerlings should achieve the full smolt production potential of approximately 3,700 fish, assuming that fall fingerling to smolt survival is 16%. Stocking at this level would be needed for four to five years.

The second option envisages a series of two pools near the center of the falls - one at the lip of the fall, the other immediately upstream from it - and a deepening of the plunge pool at the base of the falls. This would capitalize on the 3.0 - 3.3 m range maximum leaping ability of salmon, provided that water discharging over the falls is near vertical and the jumping pool is 1.25 x the height of the waterfall (Stuart 1962). The cost of this option is estimated \$25,000-\$30,000. Seeding salmon above the falls (option 1) should also be considered.

The third option foregoes the construction of fish-passage provisions and instead relies on annual seining of adult salmon at the base of the falls and lifting them above it. The adult returns would originate from hatchery stocking, as in the preceding two options, and from subsequent natural spawning and straying.

The fourth option simply maintains the status quo whereby Dunbar Stream would be managed solely for the existing brook trout resource. This option conflicts with the demand for increased salmon angling opportunity in the Nashwaak River. In 1968, approximately 67% of the total salmon angling effort in the entire Saint John River system occurred in the Nashwaak River (Appendix A) (Smith 1981). Salmon angling effort in the Nashwaak River has risen from an average of 2,781 rod-days in 1965-67 to 4,485 rod-days in 1980-82. Angling quality is usually a function of stock availability - the lower the stocks, the lower the catch-per-unit of angling effort, other things being equal.

Option 2 is judged to be the best means of developing a self-sustaining salmon run above Dunbar Falls. Its capital cost is lower than for option 1 and unlike option 3, there is no continuing need for operating costs to capture and transport adult salmon above the falls.

Salmon enhancement in Dunbar Stream would:

- (1) provide a more diversified sportfishery in the stream itself, albeit likely confined to the area immediately below the falls;
- (2) help satisfy the ever-increasing demand for quality sportfishing for salmon in the Nashwaak River;
- (3) make more efficient use of the fish rearing potential of the stream and;
- (4) make more salmon available for potential harvest in commercial fisheries.

The enhancement of Dunbar Stream for Atlantic salmon production should not adversely effect the production of brook trout. Most rivers producing Atlantic salmon in North America are cohabited with brook trout (Gibson 1973). Keenleyside (1962) and Gibson (1966, 1973) have shown a degree of habitat separation between brook trout and Atlantic salmon in shallow rivers which offsets the effects of

cohabitation. Small streams like the Dunbar are also relatively more productive than large streams (Hynes 1970), and the more plentiful food supply should assist trout to cohabitate with salmon parr (Gibson 1978).

Where shallow riffles and deeper pools alternate, salmon parr occur mainly in the faster flowing water of riffles, while brook trout occur mainly in the slower, deeper water of pools. In rapids where rocks provide shelter from the current, both species thrive (Gibson 1966 and 1973). Trout prefer shaded areas, whereas salmon parr will feed in open sunlit areas over rough bottom substrate (Gibson 1966). Brook trout prefer summer water temperatures between 14°-16°C (Ferguson 1958) and about 8°C in winter (Sullivan and Fisher 1953), while Atlantic salmon juveniles prefer temperatures about 17°C (Javaid and Anderson 1967). The genus Salmo appears to be physiologically suited for activity at somewhat higher water temperatures than does the genus Salvelinus (Fry 1948). The behavioral characteristics and habitat preferences of the two species likely minimize the negative impacts of introducing Atlantic salmon into "trout waters" and allow a more productive use of the whole habitat.

The food of trout and salmon parr is similar (Elson 1940) and both species take food from the surface drift as well as the stream bottom (Gibson 1973). Brook trout and salmon do not prey significantly on each other as both are primarily insectivorous (Elson 1940; Benson 1953; Keenleyside 1967).

Given the contentious issue of introducing Atlantic salmon into brook trout waters and concerns over diminishing the aesthetic appeal of Dunbar Falls by construction of a fish pass, it may be better to forego the provision of a fish pass in favor of an annual stocking program with hatchery-reared fall fingerling salmon. Any introduction of juvenile salmon above the falls should be studied to determine its effects on the growth and survival of resident brook trout. The study results would provide a base for reconsidering a salmon colonization strategy for Dunbar Stream.

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TABLE 1. Fish habitat characteristics of surveyed sections of Dunbar Stream, Nashwaak River, New Brunswick.

Location	Surveyed		Mean		Area of habitat (m ²) ^a						Bottom type (%)						Shade ^b
	Distance (km)	Area (m ²)	Width (m)	Depth (cm)	Riffle	Run	Flat	Skill	Pool	Silt	Sand	Gravel	Cobble	Boulder	Bedrock		
Dunbar Stream (main stem)	2.3	28,977	12.6	17	19,764 (68.2)	8,332 (28.8)	286 (1.0)	175 (0.6)	420 (1.4)		1.5	7.0	28.9	55.9	6.7	0-M	
South Branch Dunbar Stream (main stem)	7.3	43,180	5.9	12	24,461 (56.6)	10,966 (25.4)	4,457 (10.3)	1,040 (2.4)	2,256 (5.2)	3.0	4.7	9.9	58.9	21.7	1.8	M-D-0	
North Branch Dunbar Stream (main stem)	2.9	20,237	7.2	14	17,317 (85.6)	914 (4.5)		95 (0.5)	1,911 (9.4)	0.3	1.0	8.8	82.2	4.7	2.9	M-0	
Tinkettle Brook	1.6	8,270	5.2	13	6,121 (74.0)	323 (3.9)			1,826 (22.1)	8.1	5.6	4.1	78.4	3.4	0.3	D-M	
Seymour Brook	1.1	5,730	5.2	10	4,038 (70.5)	288 (5.0)	312 (5.4)	124 (2.2)	968 (16.9)	4.1	1.8	11.8	72.7	7.3	2.3		
Total	15.2	106,395			71,701 (67.4)	20,823 (19.6)	5,055 (4.8)	1,434 (1.4)	7,381 (6.9)								

^a Figures in parentheses are percentages of the total area.^b The degree of shading is ranked from highest to lowest occurrence, 0 = open (<25%), M = moderate (25%-75%), D = dense (>75%).

TABLE 2. Quantity, quality, and type of nursery habitat for Atlantic salmon parr in surveyed sections of Dunbar Stream, Nashwaak River, New Brunswick.

Location	Distance covered (km) ^a	Nursery habitat (m ²) ^b					Total
		Good (RR)	Fair (RR)	(RR)	(F)	Marginal (S)	
Dunbar Stream, main stem	2.3	27,206		890	286	175	1,771
South Branch Dunbar Stream, main stem	7.3	34,543	780	104	4,457	1,040	7,857
North Branch Dunbar Stream, main stem	2.9	18,231				95	2,006
Tinkettle Brook	1.6	6,444					1,826
Seymour Brook	1.1	4,326			312	124	1,404
Total	15.2	90,750	780	994	5,055	1,434	14,864

^a All distances are taken from the mouths of the respective streams or stream sections to the furthest upstream point of the survey.

^b The letters in parentheses designate the habitat type: RR = riffle and run, F = flat, S = still, P = pool.

TABLE 3. Atlantic salmon spawning habitat in surveyed sections of Dunbar Stream, Nashwaak River, New Brunswick.

Location	Distance surveyed (km)	Salmon spawning habitat area (m ²)		
		Good	Fair	Total
Dunbar Stream (main stem)	2.3		1,450	1,450
South Branch Dunbar Stream (main stem)	7.3	1,155		1,155
North Branch Dunbar Stream (main stem)	2.9	4,200	975	5,175
Tinkettle Brook	1.6	108		108
Seymour Brook	1.1	759	104	863
Total	15.2	6,222	2,529	8,751

TABLE 4. Potential holding and resting pools for adult Atlantic salmon, Dunbar Stream, Nashwaak River, New Brunswick.

Stream	Distance surveyed (km) ^a	Number of pools		Location (km from mouth of respective stream)	Holding pools	
		Resting pools (< 1.8 m depth)	Holding pools (> 1.8 m depth)		Estimated depth (m) ^b	Estimated area of pool (m ²) ^c
Dunbar Stream (main stem)	2.3	11	1	0.8	2.1	103
South Branch Dunbar Stream (main stem)	7.3	31	4	3.7	2.0	36
				4.2	2.0	80
				4.7	2.0	100
				5.3	3.0	60
North Branch Dunbar Stream (main stem)	2.9	9	5	1.8-1.9	2.0	375
				1.8-1.9	2.0	240
				2.1-2.2	2.0	14
				2.1-2.2	2.0	525
Tinkettle Brook Seymour Brook	1.6 1.1	9 4	1 1	2.9	2.0	105
				0.9	3.9	Pond
				0.4	2.0	200

a All distances are continuous as measured from the mouth of the respective streams.

b Depths were not actually measured and hence are only approximations.

c The estimated pool areas were derived from the estimated lengths and widths and hence are only approximations.

TABLE 5. Measurements of pH, specific conductance and total dissolved solids (TDS) for water-sampling sites on Dunbar Stream, Nashwaak River, New Brunswick, 1983^a.

Site no. ^b	Location	pH	Specific conductance at 25°C (µmhos/cm)	TDS (ppm)
	<u>Dunbar Stream</u>		22	11
1*	main stem	7.40	51	44
3*	main stem	7.21	56	47
Mean		7.31	54	45
	<u>South Branch Dunbar Stream</u>			
4	unnamed tributary	6.24	23	24
5	main stem	6.84	41	36
6	main stem	6.50	47	41
7	unnamed tributary	6.73	87	69
8	unnamed tributary	6.38	47	41
Mean		6.54	49	42
	<u>North Branch Dunbar Stream</u>			
9*	Tinkettle Brook	7.16	52	44
10*	Tinkettle Brook	6.73	44	39
11*	Seymour Brook	7.39	74	61
12	Seymour Brook	7.55	102	80
Mean		7.21	68	56
Overall mean		6.93	56	48

^a See Fig. 1 for site locations; site numbers marked with an asterisk are sites where fish sampling was also conducted.

^b All samples collected August 19, 1983.

TABLE 6. Periodic measurements of water temperature in Dunbar Stream, Nashwaak River, New Brunswick, 1983.

Date	Water temperature (°C)	Time period recorded (hrs)	Location
July 6	14.8-16.0	1300-2400	Dunbar Stream, near mouth
7	13.3-19.0	0100-2400	Dunbar Stream, near mouth
Aug 8	22.0	1700	Dunbar Stream, near mouth
9	16.0	1100	Dunbar Stream, near mouth
10	16.0-19.0	1020-1507	Dunbar Stream, main stem
11	12.0-16.5	0945-1348	South Branch Dunbar Stream
15	12.0-14.0	0945-1238	North Branch Dunbar Stream
16	10.0-14.0	1010-1231	Seymour Brook
	13.0-18.0	1000-1449	Tinkettle Brook
	23.0	1555	Dunbar Stream, near mouth
17	16.5-18.0	1120-1325	South Branch Dunbar Stream
	21.0	1445	Dunbar Stream, near mouth
19	17.0	1140	Dunbar Stream, near mouth
23	17.0	1630	Dunbar Stream, near mouth
	16.0	1000	North Branch Dunbar Stream
24	16.0	1000	Seymour Brook
	16.0	1115	Tinkettle Brook
	17.0	1330	Dunbar Stream, near mouth
25	17.5	1200	Dunbar Stream, near mouth

TABLE 7. Periodic measurements of river flow in Dunbar Stream near its mouth, Nashwaak River, New Brunswick, 1983.

Date	Flow ($\text{m}^3 \cdot \text{s}^{-1}$)
July 06	2.3
12	0.5
Aug 08	0.3
09	0.7
10	0.4
16	0.3
17	0.3
19	0.5
24	0.1
Sept 01	0.3
Nov 07	3.5

TABLE 8. Fish sampling by electrofishing in Dunbar Stream, Nashwaak River, New Brunswick, 1983.

Location	Site No. ^a	Sampling Area			Brook trout	Atlantic salmon			Slimy sculpin	Burbot	Cyprinid	American eel
		Length (m)	Av. width (m)	Area (m ²)		Fry	Small parr	Large parr				
Dunbar Stream	1	60.5	11.2	677.6	0	9	16	3			_b	_b
Dunbar Stream	2	64.4	9.0	579.6	0	4	29	2		2	9	_b
Dunbar Stream ^c	3	504.0	10.7	5,392.8	172	0	0	1	24		73	130
Tinkettle Brook	9	68.9	3.7	254.9	54	0	0	0	15			
Tinkettle Brook	10	72.8	2.8	203.8	27	0	0	0	6			
Seymour Brook	11	71.7	3.6	258.8	68	0	0	0	13			

^a See Figure 1.

^b Numbers uncaptured.

^c The actual fish count in two complete sweeps of the area.

TABLE 9. Cumulative length-frequency distribution of brook trout, Salvelinus fontinalis, in Dunbar Stream, Nashwaak River, New Brunswick, 1983.

Length-class mid-point (cm) ^a	Cumulative		Length class mid-point (cm) ¹	Cumulative	
	Number of fish	Frequency (%)		Number of fish	Frequency (%)
3.2	18	5.6	11.2	212	66.0
3.7	19	5.9	11.7	233	72.6
4.2			12.2	239	74.5
4.7	20	6.2	12.7	244	76.0
5.2	22	6.9	13.2	254	79.1
5.7	34	10.6	13.7	267	83.2
6.2	54	16.8	14.2	281	87.5
6.7	86	26.8	14.7	293	91.3
7.2	112	34.9	15.2	301	93.8
7.7	135	42.1	15.7	305	95.0
8.2	144	44.9	16.2	310	96.6
8.7	154	48.0	16.7	314	97.8
9.2	162	50.5	17.2	319	99.4
9.7	168	52.3	17.7		
10.2	181	56.4	18.2	320	99.7
10.7	193	60.1	22.2	321	100.0

^a The length-classes were 0.5 cm long; the length of fish was the fork length as measured from the tip of the snout to the fork of the tail.

TABLE 10. Age-length frequency distribution of juvenile Atlantic salmon, Salmo salar, in Dunbar Stream, Nashwaak River, New Brunswick, 1983^a.

Length class (cm)	Age		Total	
	1+	2+	No.	%
9.0- 9.9	1		1	3.1
10.0-10.9	4		4	12.5
11.0-11.9	7		7	21.9
12.0-12.9	6		6	18.8
13.0-13.9	2	5	7	21.9
14.0-14.9		3	3	9.4
15.0-15.7		2	2	6.2
16.0-16.9		1	1	3.1
17.0-17.9		1	1	3.1
Total ^b	20 (62.5)	12 (37.5)	32	(100.0)
Mean length (cm)	11.6	14.5		
SD	1.1	1.5		

^a The data include the juvenile salmon from sampling sites 1 and 2 (Fig. 1) below Dunbar Falls.

^b Figures in parentheses are percentages of the total fish sampled.

TABLE 11. Age-frequency and mean lengths of Atlantic salmon parr in the Nashwaak River as a whole, compared with that of the Dunbar Stream tributary.

Location ^a	Year	Percent of total salmon parr			Mean fork length (cm)		
		1+	2+	3+	1+	2+	3+
Nashwaak River	1968	42.4	57.6		8.6	12.5	
	69	31.9	68.1		8.6	11.4	
	70	51.4	44.9	3.7	9.9	12.7	14.7
	71	74.1	22.6	3.3	9.9	13.6	14.8
	72	84.0	16.0		10.4	13.7	
	73	66.5	33.5		10.4	13.1	
	74	78.8	21.2		11.1	14.3	
	75	76.0	24.0		9.6	13.2	
	76	82.9	17.1		9.8	13.0	
	77	66.7	33.3		9.0	12.8	
	78	66.7	33.3		9.5	12.3	
	$\bar{x}$	65.6	33.8	0.6	9.7	13.0	14.8
	83	62.5	37.5		11.6	14.5	
Dunbar Stream	83	62.5	37.5		11.6	14.5	

^a Data for Nashwaak River (1968-78) from Francis (1980).

TABLE 12. Potential bird predators of brook trout and juvenile Atlantic salmon, Dunbar Stream, Nashwaak River, New Brunswick, 1983.

Location	Distance covered (km)	Number of kingfishers	Number per	
			km	ha
Dunbar Stream	2.3	7	3.0	2.4
South Branch Dunbar Stream	7.3	5	0.7	1.2
North Branch Dunbar Stream ^a	2.9	9	3.1	4.4
Tinkettle Brook	1.6	2	1.2	2.4
Seymour Brook	1.1	0	0.0	0.0
Total	15.2	23	1.5	2.2

^a One great blue heron was observed in this tributary.

TABLE 13. Complete and partial obstructions to Atlantic salmon passage, Dunbar Stream, Nashwaak River, New Brunswick, 1983.

Location	Kilometre section no. ^a	Number of obstructions	Degree of obstructions ^b	Nature of obstruction
• Dunbar Stream (main stem)	1	1	C	A natural ledge falls (Dunbar Falls) 3.35 m high
• South Branch	2	1	P	Deadfall (trees)
Dunbar Stream	3	5	P	Deadfall
(main stem)	4	2	P	Deadfall
	5	1	P	Deadfall
North Branch	1	3	P	Deadfall
Dunbar Stream	2	2	P	Deadfall
(main stem)				
Tinkettle Brook	1	8	P	Deadfall
	2	2	P	Deadfall
		2	P	Beaver dams and deadfall
		1	P	Log jam and deadfall
Seymour Brook	2	1	P	Deadfall
	3	5	P	Deadfall
	4	2	P	Deadfall
	5	3	P	Deadfall

^a Measured from the mouth of the respective stream.

^b "C" denotes a complete obstruction to fish passage; P = denotes a partial obstruction to fish passage at low stream flows.

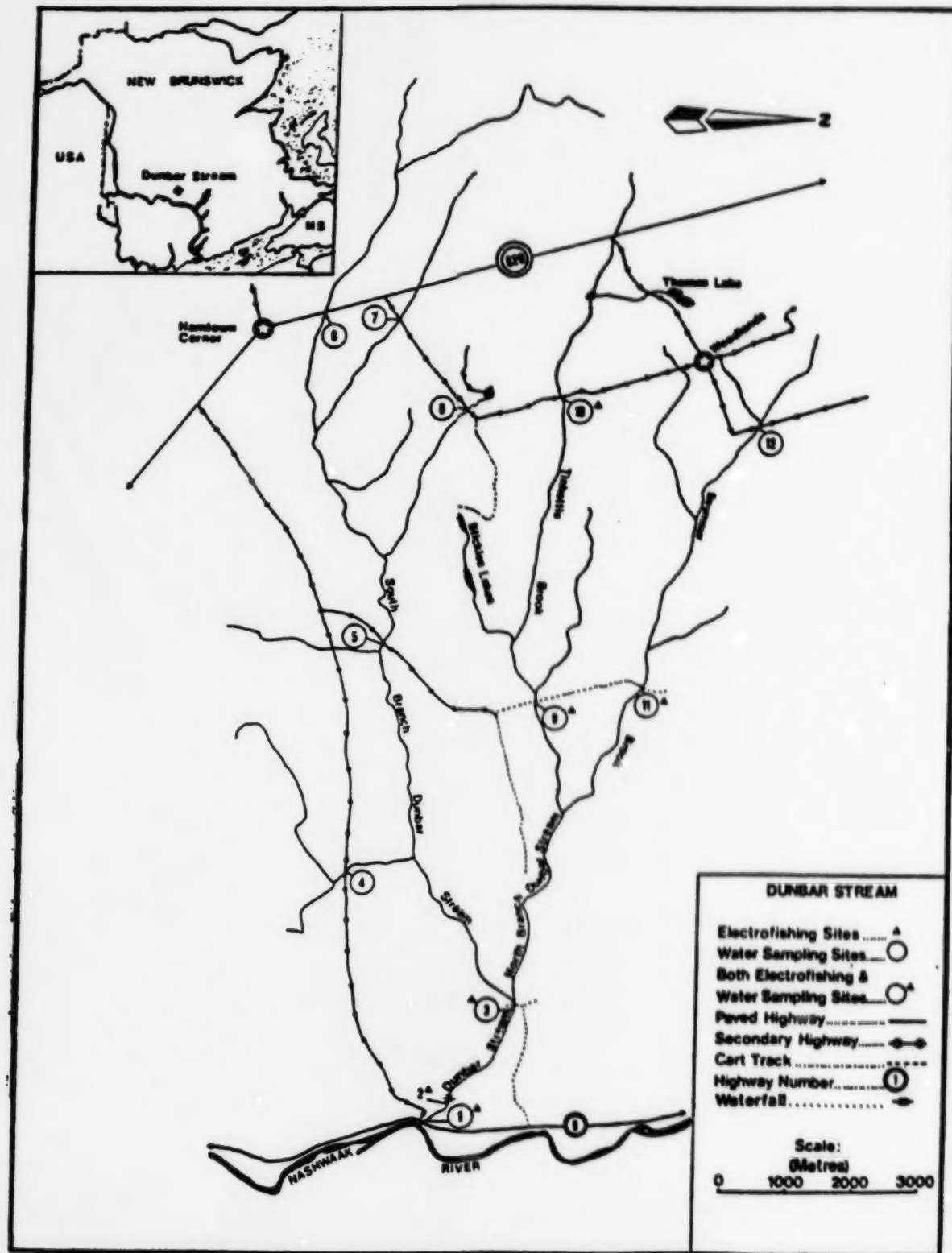


Figure 1. Dunbar Stream and the location of fish sampling and water quality sites, Nashwaak River, New Brunswick, 1983.

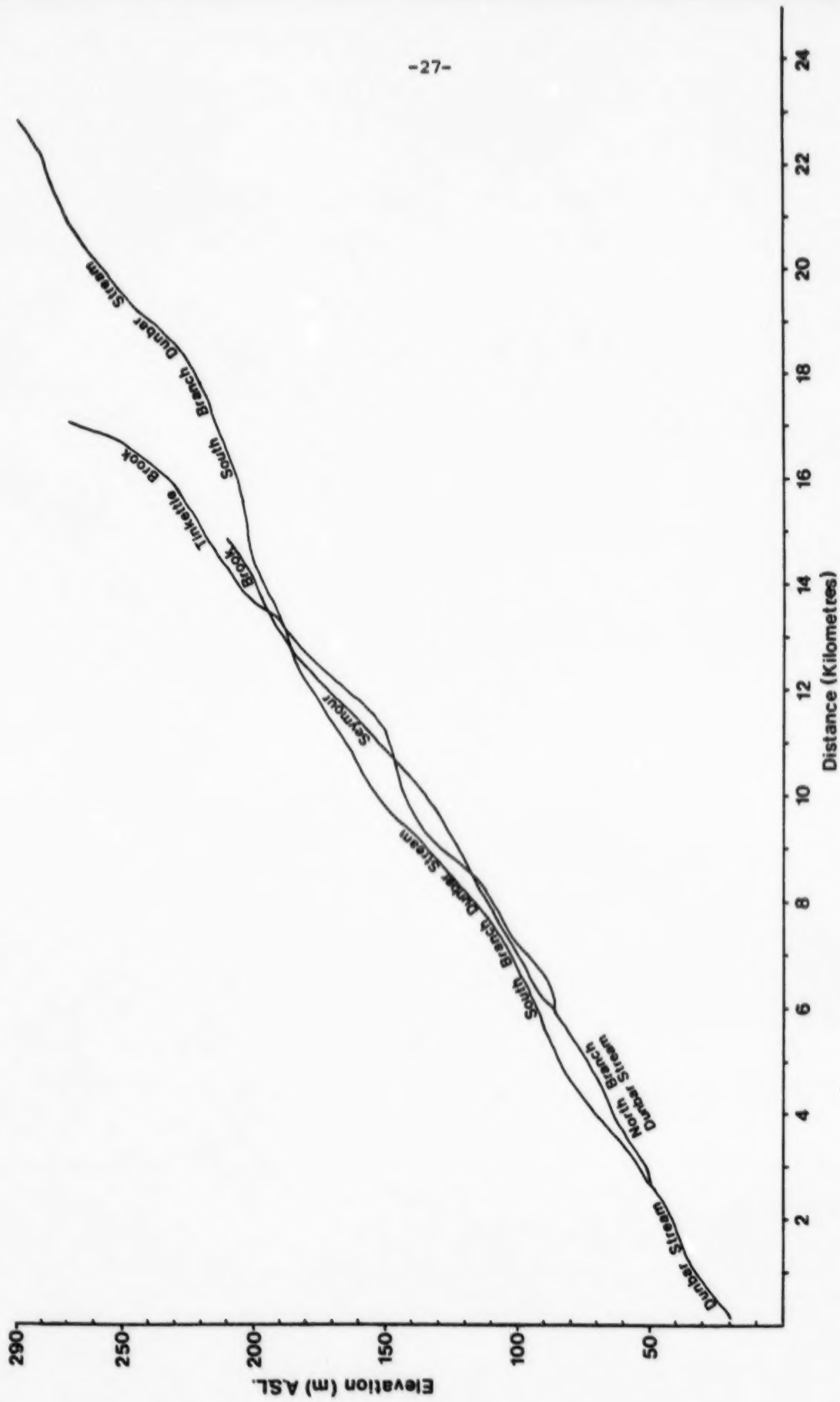


Figure 2. Stream gradient profile, Dunbar Stream, Nashwaak River, New Brunswick.

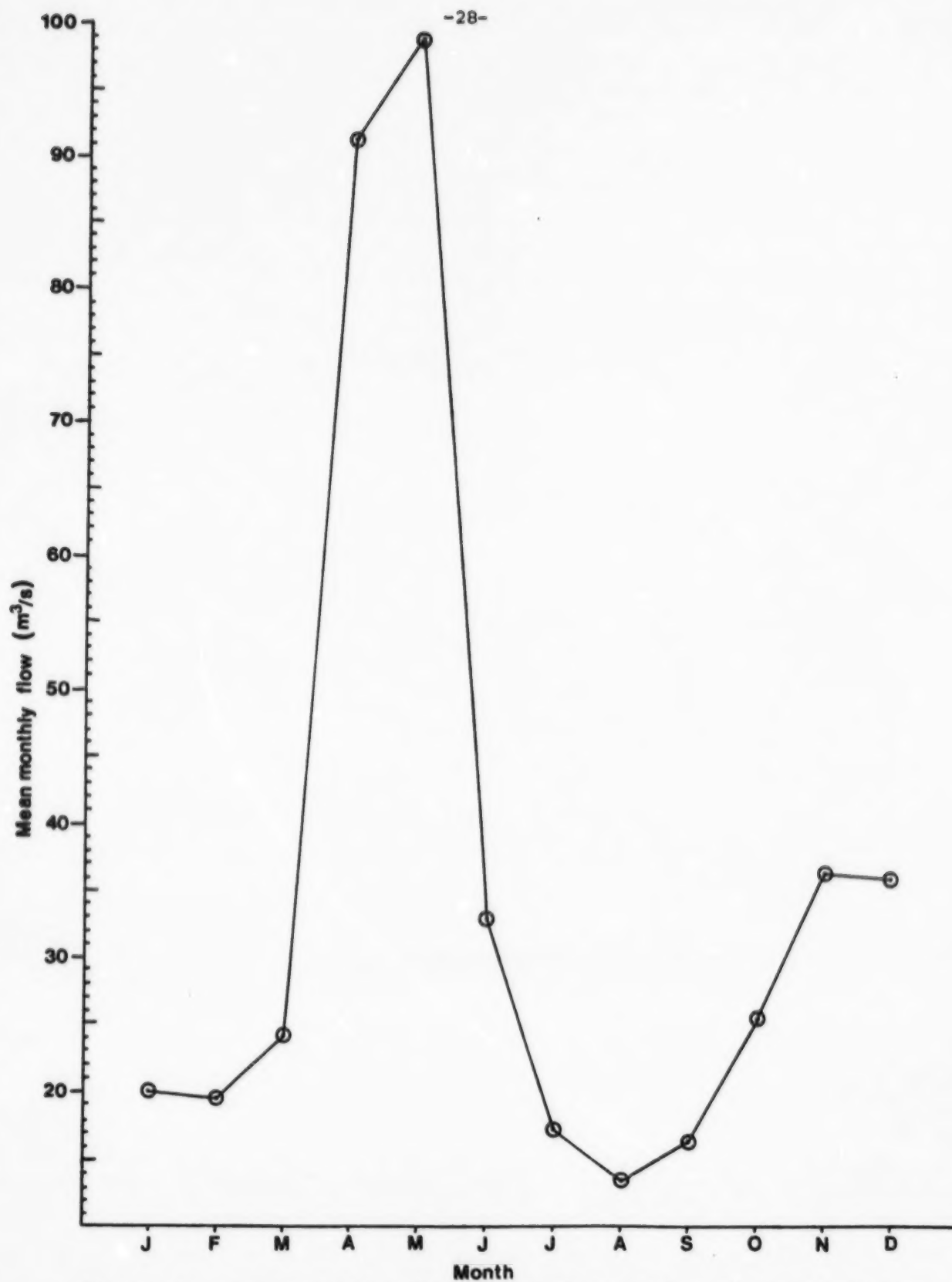


Figure 3. Mean monthly flows at Durham Bridge, Nashwaak River, New Brunswick (1962-79).

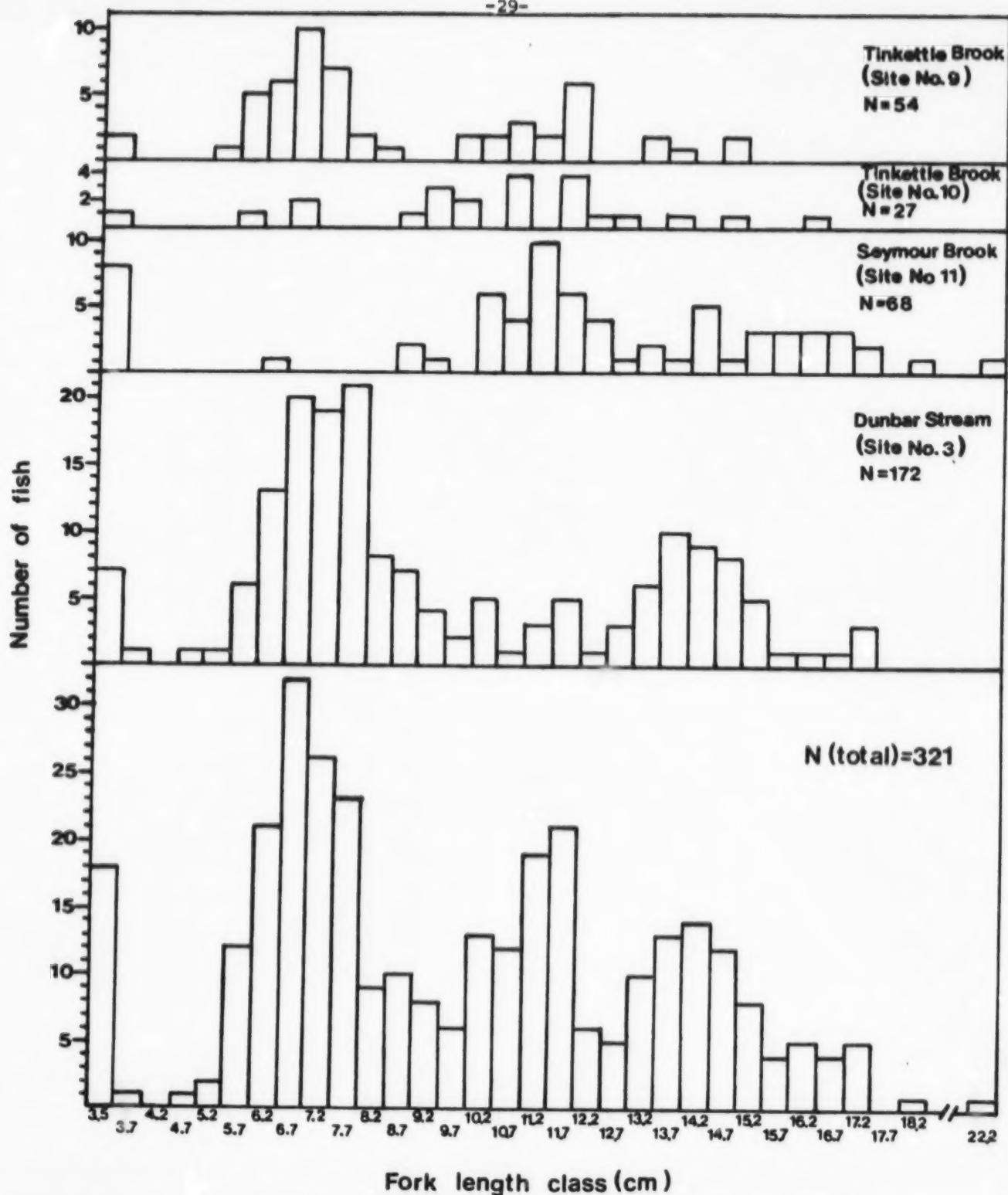


Figure 4. Frequency distribution of brook trout, *Salvelinus fontinalis*, fork lengths, Dunbar Stream, Nashwaak River, New Brunswick, 1983. (half-cm length classes with midpoints shown on x-axis).

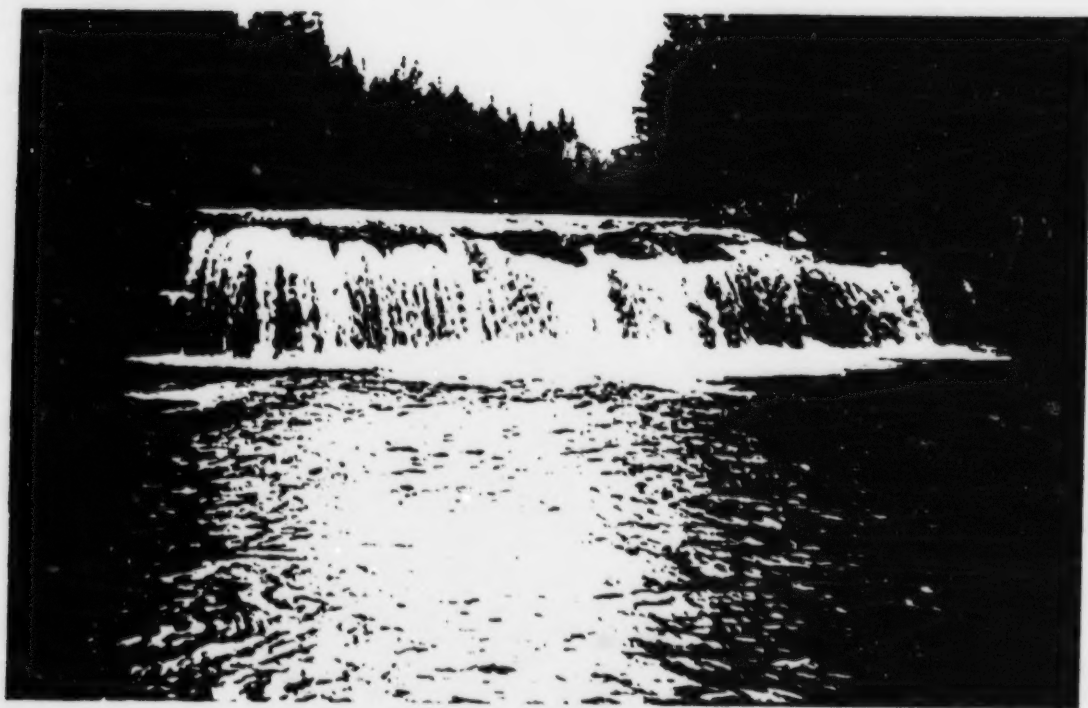


Figure 5. View of lower side of Dunbar Falls, Dunbar Stream.

APPENDIX A

Annual Atlantic salmon angling catch and effort for the entire Saint John River system and Nashwaak River tributary, New Brunswick, 1951-82.^a

Year	Saint John River System				Nashwaak River			
	Black salmon and grilse	Bright salmon and grilse	Total salmon and grilse	Angling effort (rod-days)	Black salmon and grilse	Bright salmon and grilse	Total salmon and grilse	Angling effort (rod days)
1951	282	3,401	3,683	6,539		383	383	2,166
52	397	2,876	3,273	10,293		19	19	1,225
53	128	3,720	3,848	9,195		34	34	1,176
54	118	2,488	2,606	5,608		9	9	3,761
55	32	1,756	1,788	15,286		20	20	2,585
56	24	2,328	2,352	9,583		5	5	3,877
57	45	2,096	2,141	4,359		6	6	3,021
58	66	2,856	2,922	9,961		19	19	2,991
59	198	2,105	2,303	12,757		15	15	1,736
60	61	2,242	2,303	10,596		7	7	1,186
61	88	1,127	1,215	7,473		11	11	2,877
62	105	688	793	7,217		13	13	4,243
63	36	4,070	4,106	11,445		14	14	4,801
64	86	3,422	3,508	11,093		34	34	2,441
65	96	3,006	3,102	9,357		204	256	2,870
66	208	1,955	2,163	8,386	52	206	259	2,974
67	206	374	580	4,875	24	98	122	2,388
68	100	197	297	3,573	16	74	90	3,234
69	74	972	1,046	7,410	6	40	46	4,420
70	40	1,716	1,756	6,904	50	110	160	4,075
71	120	1,590	1,710	7,713	26	71	97	4,780
72	71	2,099	2,170	8,010	52	92	144	5,790
73	92	2,274	2,366	12,162	42	64	106	2,425
74	73	2,353	2,426	13,178	122	173	295	3,675
75	181	3,120	3,301	14,300	146	271	417	4,300
76	295	4,558	4,853	16,843	133	250	383	3,775
77	251	4,021	4,272	19,210	72	113	185	2,147
78	118	1,084	1,202	11,684	28	47	75	2,150
79	47	2,340	2,387	13,354	30	1,116	1,146	4,085
80	45	5,271	5,316	25,800	24	883	907	3,775
81	38	2,294	2,332	24,677	49	1,289	1,338	5,596
82	49	4,472	4,521	37,685				

^a Table adapted from Smith (1981).

APPENDIX B

Fish habitat characteristics summarized by one-kilometre sections, Dunbar Stream, Nashwaak River, New Brunswick.

Location	Kilometre section number ^a	Area (m ²)	Mean width (m)	Mean depth (cm)	Area (m ²) of habitat types					Percent					Shade ^b	
					Riffle	Run	Flat	Still	Pool	Silt	Sand	Gravel	Cobble	Boulder		Bedrock
Dunbar Stream (main stem)	1	14,147	14.2	18	9,490	4,184	64	142	267		0.5	6.5	25.5	52.5	15.0	O-M
	2	11,870	11.9	17	9,464	2,134	119		153		2.5	8.0	33.5	56.0		O-M
	3 (0.3)	2,960	9.9	15	810	2,014	103	33			1.7	5.0	25.0	66.7	1.7	0
South Branch Dunbar Stream (main stem)	1	7,450	7.4	14	3,632	3,394	392	20	12	0.5	4.0	9.5	30.5	50.5	5.0	M-O
	2	8,240	8.2	12	3,818	3,336	633	441	12	2.5	6.0	11.5	35.5	43.5	1.0	O-M
	3	6,920	6.9	14	3,056	1,555	1,371	564	374	5.5	6.5	9.5	53.0	25.5		M-O-O
	4	5,030	5.0	13	3,747	198			1,084	1.5	0.5	5.5	91.0	1.5		M-O-O
	5	4,910	5.0	12	4,171	219			520		1.0	8.0	83.5	7.0	0.5	D-M
	6	4,720	4.7	10	3,082	1,208	270	15	145	2.0	4.0	10.0	73.5	8.5	2.0	D-O-M
	7	4,780	4.8	10	2,469	1,056	1,151		104	3.5	7.0	15.5	51.0	18.0	5.0	D-M-O
	8 (0.3)	1,130	4.4	13	486	640			4	20.0	16.7	10.0	40.0	13.3		M-O
North Branch Dunbar Stream (main stem)	1	6,797	7.4	12	6,277	334		95	91			8.5	86.0	5.0	0.5	M-O
	2	7,010	7.0	14	5,938	312			760	1.0	3.0	11.0	80.0	2.5	2.5	M
	3 (0.9)	6,430	7.1	15	5,102	268			1,060			6.7	80.6	6.7	6.1	M
Tinkettle Brook	1	4,760	4.8	12	4,259	225			276	3.0	2.5	4.0	85.0	5.0	0.5	D-M
	2 (0.6)	3,510	5.8	16	1,862	98			1,550	16.7	10.8	4.2	67.5	0.8		D-M
Seymour Brook	1	5,370	5.4	10	3,750	216	312	124	968	4.5	2.0	9.0	74.0	8.0	2.5	D-M
	2 (0.1)	360	3.6	12	288	72						40.0	60.0			D

^a The kilometre section number represents a section of stream one kilometre in length, unless followed by a number in parentheses which represents the actual length (km) surveyed. The section numbers start at the mouths of the respective streams.

^b The degree of shade is ranked by frequency of occurrence; 0 = open (< 25%), M = moderate (25%-75%), D = dense (> 75%).

APPENDIX C

Quantity, type and quality of habitat for Atlantic salmon parr summarized by 1 km sections, Dunbar Stream, Nashwaak River, New Brunswick.

Location	Kilometre section number ^a	Habitat area (m ²)						
		Good (RR)	Fair (RR)	Marginal ^b				Total
				(RR)	(F)	(S)	(P)	
Dunbar Stream (main stem)	1	12,784		890	64	142	267	1,363
	2	11,598			119		153	272
	3 (0.3)	2,824			103	33		136
South Branch Dunbar Stream (main stem)	1	6,246	780		392	20	12	424
	2	7,154			633	441	12	1,086
	3	4,611			1,371	564	374	2,309
	4	3,945					1,085	1,085
	5	4,390					520	520
	6	4,290			270	15	145	430
	7	3,525			1,151		104	1,255
	8 (0.3)	382		104	640		4	748
North Branch Dunbar Stream (main stem)	1	6,611				95	91	186
	2	6,250					760	760
	3 (0.9)	5,370					1,060	1,060
Tinkettle Brook	1	4,484					276	276
	2 (0.6)	1,960					1,550	1,550
Seymour Brook	1	3,966			312	124	968	1,404
	2 (0.1)	360						

^a The kilometre section number represents a section of stream 1 km in length, unless followed by a number in parentheses which represents the actual length surveyed. The section numbers start at the mouths of the respective streams.

^b RR = riffle and run, F = flat, S = still, P = pool

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APPENDIX D

Quantity and quality of Atlantic salmon spawning habitat by one-kilometre sections, Dunbar Stream, Nashwaak River, New Brunswick.

Location	Kilometer section number ^a	Salmon spawning habitat area (m ²)		
		Good	Fair	Total
Dunbar Stream (main stem)	(2.3)		1450	1,450
South Branch Dunbar Stream (main stem)	1	136		136
	2	159		159
	6	795		795
	7	65		65
North Branch Dunbar Stream (main stem)	1	1,538	582	2,120
	2	402	392	794
	3 (0.9)	2,261		2,261
Tinkettle Brook	1	108		108
Seymour Brook	1	759	104	863

^a The kilometer section number represents a section of stream one kilometer in length unless followed by a number in parenthesis which represents the actual length surveyed. The section numbers start at the mouth of the respective streams.

APPENDIX E

Summary of the distribution of salmon holding and resting pools by 1 km sections, Dunbar Stream, Nashwaak River, New Brunswick.

Location	Kilometre section number ^a	Number of pools	
		Resting pools (< 1.8 m deep)	Holding pools (> 1.8 m deep)
Dunbar Stream (main stem)	1	8	1
	2	3	
South Branch Dunbar	1	3	
Dunbar Stream (main stem)	2	2	
	3	4	
	4	8	1
	5	5	2
	6	5	1
	7	3	
	8 (0.3)	1	
North Branch Dunbar	1	3	
Dunbar Stream (main stem)	2	2	2
	3 (0.9)	4	3
Tinkettle Brook	1	5	1
	2 (0.6)	4	
Seymour Brook	1	3	1
	2 (0.1)	1	

^a The kilometre section number represents a section of stream 1 km in length, unless followed by a number in parentheses which represents the actual length surveyed. The section numbers start at the mouth of the respective streams.